Naval Surface Warfare Center
Carderock Division
West Bethesda, MD 20817-5700

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Ship Systems Integration & Design Department

Technical Report

MOSES Support Platform

By

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This paper describes a concept design for a mobile support platform for the deployment, retrieval, and operation of the MOSES inflatable causeway. The system provides the capability to unload vehicular cargo at locations without port facilities without driving the vehicles through the surf zone. The platform is based on a commercially available jack-up barge with additional machinery and equipment fitted to deploy and retrieve MOSES. The platform is intended to require as little human oversight as possible. Together with MOSES, the platform provides a self-sufficient vehicle offloading system, which provides the functionality of conventional temporary causeways with a significant reduction in cost, weight and set-up time.

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Inflatable Causeway, MOSES, CISD, jack-up barge, amphibious operations, logistics, Concept Design, Ship-to-Shore

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Abstract

This paper describes a concept design for a mobile support platform for the deployment, retrieval, and operation of the MOSES inflatable causeway. The system provides the capability to unload vehicular cargo at locations without port facilities without driving the vehicles through the surf zone. The platform is based on a commercially available jack-up barge with additional machinery and equipment fitted to deploy and retrieve MOSES. The platform is intended to require as little human oversight as possible. Together with MOSES, the platform provides a self-sufficient vehicle offloading system, which provides the functionality of conventional temporary causeways with a significant reduction in cost, weight and set-up time.

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Introduction

Mission Statement

The objective of this project was to design a platform from which an inflatable causeway could be deployed and sustained. The platform must contain all the necessary machinery and equipment to deploy, operate the causeway with minimal human involvement. The platform must also be easily moved and secured in position and serve as a mooring point for cargo vessels.

Background

The inflatable causeway concept (MOSES[i]) permits the discharge of vehicular cargo from a ship to the shore where no port access is available. The deployment environment will not be immediately hostile, although the causeway must be designed with the ability to sustain damage either from the environment or enemy action. Conventional causeway systems such as the Marine Causeway System (MCS) and the Light Marine Causeway System (LMCS) are bulky and assembled in situ, which can take up to a day. As a result, a better solution in terms of deployment speed, cost and weight is being sought.

A team of summer interns working at the CISD developed the MOSES concept. The primary structure of the inflatable causewy is a large fabric bag structure filled with water under a small amount of hydrostatic pressure. The bag also includes air beam superstructures which primarily support a water reservior providing the hydrostatic head to pressurize the bag and provide protection from the sea. A roadway surface consisting of synthetic planks protects the fabric from the wheels and tracks of military vehicles.

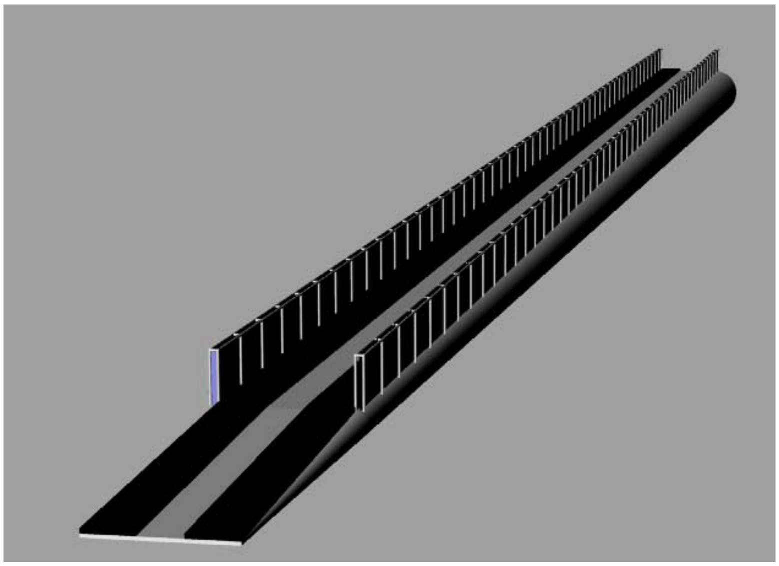


Figure 1 – MOSES Inflatable Causeway

The MOSES team designed the causeway to be deployed from a low draft ship. However, this would not be the optimal solution as it would be difficult for vehicles from other vessels to access the causeway. The ship would also need to remain at anchor while MOSES was deployed, thus removing itself from the taskforce. In addition to these factors, a ship might require extra crew, negating one of the project requirements. An alternative to a ship is a platform which could remain static in the water, such as a jack-up barge, housing the machinery systems needed. It is intended that the entire system will be unmanned while deployed, although personnel may be needed to perform some tasks during deployment and retrieval of MOSES. Day to day running of the platform should be conducted without the necessity of a crew.

MOSES combined with a mobile support platform (MSP) would provide a self-sufficient vehicle offloading system that is considerably cheaper, more convenient, lighter and less manpower intensive than conventional amphibious causeway systems.

Jack-up units have been a part of the offshore oil industry fleet since the 1950s. They have been used for exploration drilling, tender assisted drilling, production, accommodation, and work/maintenance platforms. A jack-up barge is an offshore structure composed of a hull, legs, and a hull lifting system. When on-site, the barge can lower its legs into the seabed and elevate its hull above the surface to provide a stable work deck capable of withstanding the environmental loads. A typical modern drilling jack-up is capable of working in harsh environments (wave heights up to 80 ft, wind speeds in excess of 100 knots) in water depths up to 500 feet[ii]. Smaller platforms such as that shown in Figure 2 provide stable work platforms in less severe environments.

Figure 2 - Oil Industry Jack-Up Barge

Jack-up units are a developed and known quantity, which are commercially available. A standard unit can be modified with the necessary equipment to perform a number of roles, which would be suitable for the purpose of the MSP.

Jack-up units suited to the MSP application are available for approximately $3.2M

Design and Engineering

Objectives

The function of the MSP is to enable the operation of the MOSES system. Key objectives that need to be fulfilled in performing this include:

1. house all necessary machinery to operate MOSES;
2. provide a pier head suitable for landing RO-RO ships;
3. survive in elevated sea states;
4. rapidly deploy and retrieve MOSES; and
5. have a low cost.

Concept of Operation

The MSP concept is a self-contained unit. To deploy in-theater, a number of options are available using tugs or heavy lift ships. The platform can be towed from CONUS to an intermediate base or to the Sea Base. Modifications to the platform such as increasing the structure size and freeboard may be required to increase platform survivability in the open ocean.

Alternatively, the MSP could be transported in-theater on the deck of a heavy lift ship and floated off in the Sea Base. The platform would then be towed the short distance from the Sea Base to its deployment position.

Once it has been located in the correct spot, standard procedures would be followed for positioning a jack-up barge on the sea floor. Once positioned, MOSES can be deployed.

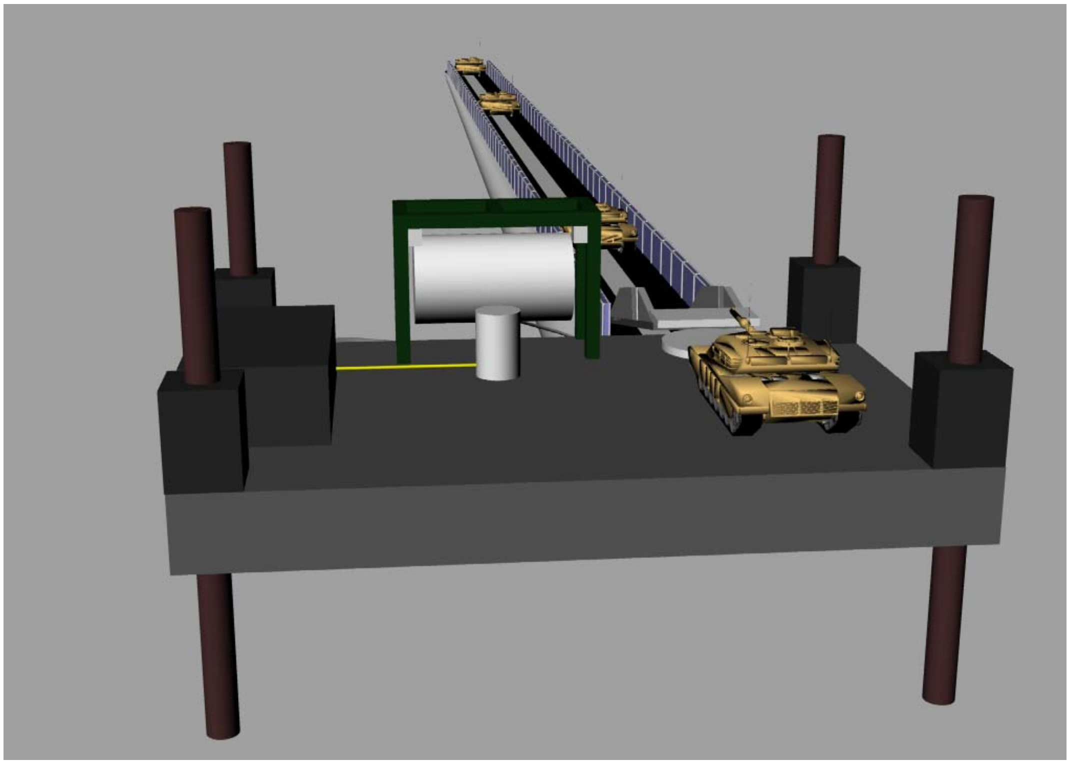


Figure 3 - MSP With MOSES Deployed

MOSES Deployment

MOSES is stowed as a rolled cylinder on the retrieval winch drum. Deployment requires several machinery systems on the MSP including seawater pumps and air compressors. When the pumps and compressors are connected to the appropriate valves on MOSES, the entire assembly is detached from the winch and allowed to drop into the sea. At this point, air pressure is increased in the air beams to a point at which the rolled MOSES cylinder begins to rotate and unroll. Air pressure is maintained until the causeway has been fully deployed. The positive buoyancy of the material allows the causeway to float, and at this point water can be pumped in to fill the fabric bag and reservoirs so that the entire structure becomes rigid.

MOSES Retrieval

Retrieval is accomplished by connecting a cable on the retrieval winch to the beach end of the fabric bag. The retrieval winch will retract a cable attached to the end of the causeway, in turn reeling in the causeway with the end at the beach coiling first. Prior to winching, valves on the causeway will be opened on the bag and air beams to relieve pressure. The volume of water contained above the waterline will drain. This will leave the end of the beach end of the causeway flaccid, requiring less winch force. When the end of the causeway is being retracted, water will be forced out of the main body as material is raised above the waterline. In this fashion, MOSES will empty itself as it is winched in. The winch is required to overcome the back pressure of the water leaving the valves, the frictional forces associated with the accumulation of environmental matter on the material, and the friction of the material on itself during winding.

The causeway will not be wound around a spool, as during deployment, the spool would be the last section to deploy, leaving it on the beach, requiring recovery or disposal. To negate the necessity for a spool, the causeway will wind around itself. Clamps mounted to a frame would secure the edges of the end of the causeway in place, while the winch rotates the clamps. This causes the material to wind round itself until it has all been collected. At this point, the causeway is contained in a roll and can be moved for stowage, or readied for re-deployment.

MSP Design

Low cost was an objective of the MSP design. The design used COTS equipment whenever possible. While data for specific manufacturer's equipment (Appendices A to E) was used in the MSP design, multiple commercial alternatives are available. The MSP design concept and deck plan are shown in Figures 4 and 5.

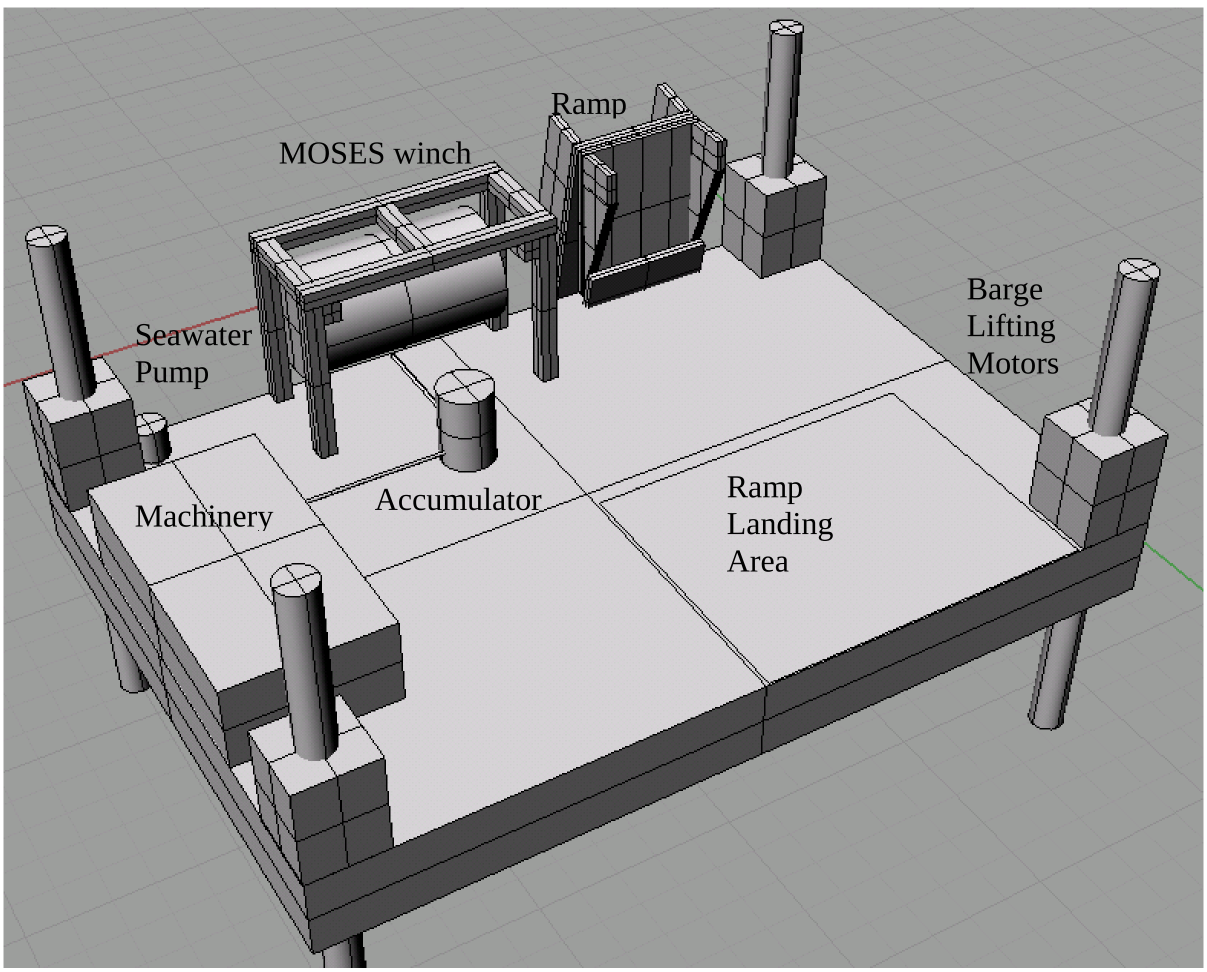


Figure 4 - Isometric Deck Plan

Principal characteristics of the MSP design are shown in table 1.

Parameter	Value
Length	80 ft
Beam	56 ft
Draft	8 ft
Freeboard	5 ft
Displacement	595 LT
Installed Power	470 hp

Table 1 - MSP Principal Characteristics

Platform

The benefits of jack-up barges include the flexibility of location, and once positioned, they do not require manning. While there are many jack-up barge vendors the barge chosen as the basis for this design is a Jack-up Barge B.V. self-elevating platform JB-107 (Appendix A) capable of operating in 6.5 ft waves. With a maximum load capacity of 250 long tons, it has adequate strength for supporting MOSES auxiliary equipment.

The jack-up mechanism is operated by a rack and pinion mechanism on each leg. The same diesel generator that powers the auxiliary equipment supplies the power for the jack-up mechanism. The barge will receive a vehicle ramp from small intra-theatre lift ships such as JHSV or landing craft. A 26 ft x 32 ft ramp receiving area has been provided on the deck of the platform. The deck area will house all the machinery and equipment required to deploy MOSES (Figure 5).

The diesel generator onboard requires a fuel supply. A 2,000 gallon fuel tank weighing 4,000 lbs has been included in the design. Operating at half load, the diesel generator consumes 22 gallons of fuel per hour. The fuel supply allows 90 hours of constant operation before a refuel is required.

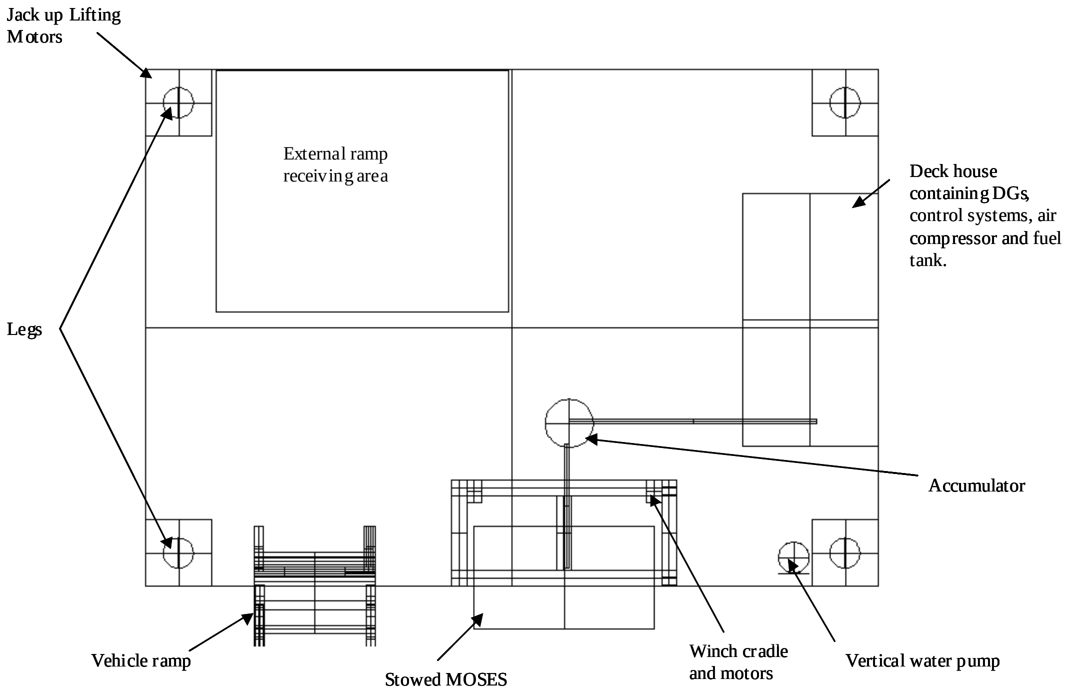


Figure 5 - Deck Plan

Air Compressor

An air compressor is required to inflate the MOSES causeway air beams. The air beams are used to unroll MOSES and provide the structural support for the reservoir of water that generates static head, in turn pressurizing the causeway. A number of requirements were placed on the compressor so that it can effectively inflate the causeway air beams. The volume required to fill the air beams is 250 cu ft at a pressure of 11.5 psig. Connected to the compressor will be an accumulator, which can contain enough air at high enough pressure to fully inflate the air beams and deploy the causeway in one charge. The accumulator is a 400-gallon tank, which can be pressurized to 5,000 psi. The presence of an accumulator is for safety and also so that the air can be bled off at the required rate. In order to ensure that the air beams remain inflated to the correct pressure even during the presence of a leak, the system is automated to sense any pressure change and adjust it accordingly. The specifications for the air compressor system are contained in Appendix B.

Object	Weight [lbs]	Power Reqd [hp]	Dimensions [ft]	Capability
Air Compressor	1,700	50	3 x 3 x 4.5	18 cu ft/min
Accumulator	2,050	-	∅5 x 8	5,000 psi

Table 2 - Air Compressor Data

Seawater Pump

The seawater pump is required to rapidly fill the causeway and reservoir so that MOSES can be deployed. Performance of the pump is governed by the requirements of the causeway. The total volume of water required is 108,000 cu ft. In order for the water to be drawn from the sea, through the pump on the jack-up barge, and into the causeway, it must overcome 12.5 ft of head plus frictional losses in the transfer pipe. The high volume low head requirement of the pump suggests that an axial flow pump would be most suitable. The pump is vertically arranged and draws water through the base of the platform. Data for the pump is contained in Appendix C.

Object	Weight [lbs]	Power Reqd [hp]	Dimensions [ft]	Capability
Pump Motor	750	150	∅3 x 3	-
Axial Pump	1,750	-	∅3 x 7	20,000 gpm @ 24’ TDH

Table 3 - Water Pump Data

Winch

The winch system is required to retrieve the causeway after deployment and is a high torque, low speed application that must be capable of supporting the spool of material on the jack-up barge. Initial estimates have allowed for a 26,000 lb static pull winch. Further analyses must be completed on the loads and forces present during winching such as the friction between various surfaces of the bag. The winch data is contained in Appendix D.

Object	Weight [lbs]	Power Reqd [hp]	Dimensions [ft]	Capability
Winch	32,790	100	17 x 11 x 14	26,500 lbs max pull

Table 4 - Winch Data

Ramp

The ramp used for MSP is the same stern ramp used on the HSV 2. It is capable of supporting a battle ready M1A1 tank. It has the ability to slew in order to connect with MOSES. It is a hydraulic folding type ramp, which can be retracted during transit of the barge and for adverse weather.

Object	Weight [lbs]	Power Reqd [hp]	Dimensions [ft]	Capability
Vehicle Ramp	20,000	-	41 x 14	Hydraulic Slewing

Table 5 - Ramp Data

Power Generation

The selected jack-up includes its own power pack that is used to supply the barge lifting motors. MOSES systems require additional power sources and the total power requirement for auxiliary machinery is 450 hp. A Cummins XC354 diesel generator (Appendix E) was selected as a power source for all systems, except the lifting motors, due to its fuel efficiency and low weight of 4 LT. It provides 470 hp that allows for system efficiency degradation over time. A single diesel was chosen over two, due to the inherent maintenance increase that would accompany a twin diesel arrangement. The extra fuel efficiency of operating two generators at higher load rather than operating one at partial load is not significant enough to offset the extra maintenance requirement on what is supposed to be a non-manpower intensive platform.

Object	Weight [lbs]	Power [hp]	Dimensions [ft]	Capability
Diesel Generator	9,300	470	14.5 x 5 x 7	-

Table 6 - Diesel Generator

Weight Estimates

The weight summary for the MSP with MOSES onboard is shown in Table 6. Since the weight of jack-up barge is a well-defined quantity and it represents eighty percent of the total system weight, a weight margin of 5% was considered appropriate. An additional 22 LT was added to account for weight estimate uncertainties and the weights of minor components such as piping and cables. A weight growth for machinery, MOSES, fuel and other components could be as much as 156 LT without exceeding the barge capacity.

Object	Weight With Margin [LT]
COTS Jack-Up Barge	345
MOSES Machinery	-
Air Compressor	*2*
Seawater Pump	*1*
Winch	*16*
Ramp	*10*
Diesel Generator	*4*
MOSES	*34*
Fuel	7
Auxiliary and Outfit	20
Unloaded	**432**
Fully Loaded	**439**

Table 7 - Weight Summary

The maximum permissible weight of the fully loaded barge is 595 LT. This should be sufficient for significant systems weight growth over time and transient loads such as those from passing military vehicles.

Systems Integration

A number of different systems are present on the MSP, all of which contribute to the operation of a single piece of equipment. For each of the systems to operate at the correct time and in the correct manner, a control system is required to oversee the individual processes and monitor system status. This adds a further aspect of automation that is a key requirement of the design and helps to ensure that problems can be managed effectively.

Physically integrating the different items of machinery is also critical, since one source of electrical power is onboard for the MOSES system so each auxiliary system on the MSP will need to be compatible with that source. All the systems must fit onto the platform in such a way that they can all operate safely and be maintained with minimum inconvenience and disruption.

The method for deploying MOSES has potential for improvement. Currently, the winch is located to the side of the ramp and human interaction is required to move the causeway under the ramp when it is in the water. To allow further automation and hence improve deployment speed and ease, the winch could be located above the ramp or even attached to it so that inflation can occur in tandem with the positioning of the ramp. Further optimization of the locations of the winch and ramp would allow deployment and retrieval of MOSES to become more efficient.

Use of an integrated power generation system for barge lifting motors and MOSES systems should be explored further.

Conclusion

Project Summary

A concept design for a self-sufficient mobile platform from which to deploy and retrieve the MOSES inflatable causeway was developed. The platform can also act as the interface between small intra-theater lift ships and MOSES. The combination of this platform and MOSES provides a capability to land vehicular cargo where no port is available. This system provides the capability of conventional causeways at a fraction of their cost, weight, and deployment time.

Recommendations for Future Work

A number of areas have been identified for further development to enhance the compatibility and efficiency of the MOSES and MSP integration.

The water pumps and air compressors are available with self-monitoring systems, however further research must be carried out on control systems and how they can be implemented to control all onboard systems.

At this level, no structural or strength calculations have been performed to assess the need for reinforcement and to accommodate for loads peculiar to MOSES such as equipment foundations, ramp fittings etc. Prior to the manufacture of a prototype, these analyses should be conducted for all relevant conditions, which the platform may experience. It must be noted that the weight of all MOSES components is considerably less than the maximum allowable cargo weight that the jack-up barge can carry. For this reason it is not envisioned that the weight of MOSES related equipment would be a limiting factor in the design of the platform. Furthermore, the robust industrial nature of jack-up barges suggests they will require little strengthening to meet MSP needs

Standard procedures are to be followed when the platform is positioned. However initial control of the platform during positioning is an area for further work. Different approaches could be utilized such as a simple anchoring arrangement or a more complex procedure performed with a ship locating the platform and holding it in place during mooring. Whatever the solution, the effect on the design of the mooring system must be considered, e.g. provision of capstans, windlasses and chain lockers for an anchor.

The deployment of MOSES relies on a relatively small volume of air to rotate and unroll it to the shore. This is an issue specific to MOSES and changes required to the mode of deployment may have an affect on the MSP system. Changes such as an increase in air pressure to force movement of the cylinder, or the replacement of air as the working fluid with water will have consequences affecting onboard systems. There is sufficient weight capacity, area, and volume in the design of the platform to allow alteration and, if necessary, expansion of MSP systems, but modifications to the MOSES systems must be considered together with their impact on the MSP. An integrated power generation system for the platform lifting motors and MOSES systems should be investigated.

Appendix A – Jack Up Barge JB 107 Data

SELF-ELEVATING PLATFORM JB-107

General	
Type	Dismountable ISO Sea container type unit
Series	SM-200
Class	Germanischer Lloyd + 100A 5 W
Call name	JB-107
Main Dimensions	
Length	24.4 metre
Width	17.1 metre
Height of pontoon	2.44 metre
Leg length x diam..	30 metre [in 1 piece] x 1.2 metre diam.
Jacking System	
Jacking stroke	1.5 metre
Maximum pay-load	250 tons
Powerpack	2 Diesel electric powerpacks
Operating Conditions	
Draft	1.45 metre
Max. water depth	20 metre [by 30 metre leg length]
Wave height	2.0 metre
Wind velocity	up to 13 metre/sec.

Appendix B – Air Compressor Data

Description:

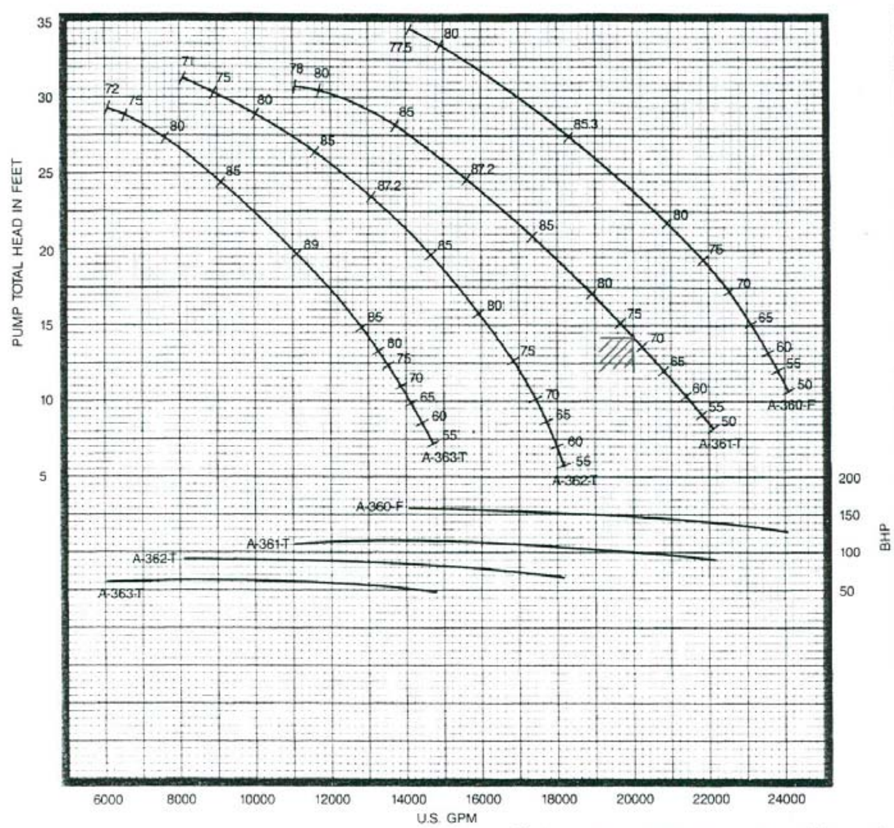
- SeaComAir 520 l/min. / 18 cfm / 32 m3/h complate system
- Mounted on powder coated, compact cabinet for stationary operation
- Cabinet colors black or blue
- (2) Main control panel
- Pressure maintaining valves
- Pressure relief valves on all stages
- (2) Fully automatic condensate drain with collector
- Final pressure switch with gauge and automatic shut-off
- (2) Hour meter
- Oil filled finel pressure gauge 0~400bar/5800psi
- (2) External oil level sight glass indicator with oil drain
- (2) Two-chem breathing air purification system with activated carbon/molecular sieve
- (2) Two External Purifucation Cartridge Holders
- Disposable purification cartridge easy to replace
- Four (4) H.P. filling hoses with on/off valve and bleed
- Filling hose with SCUBA INT yoke or DIN200/300
- Available in a variety of electric drive units to fit any requirement

Specifications:

Construction	Two (2) three stage, three cylinder high pressure compressor system all stainless steel inter-, final-stage coolers Mounted in a powder coated steel cabinet
Max Pressure	225bar/3200psi or 330bar/4700psi (option)
Max R.P.M.	1550
Approx.Output:	265 l/min-9 cfm-16 m3/h per system
Oil Type	SeaComAir synthetic compressor oil
Oil Capacity	(2) 1,5 Liters / 51 oz.
Drive Motors	(2) 5,5kW 400V/50Hz o.60Hz el.motor 3phase
Features:	(2) Automatic condensate drain system Final pressure switch with gauge and automatic shut-off (2) Hour meter, (2) On/Off Switch
Filling Connection	Four (4) filling hose with INT or DIN valve
Refill Time per system	10 Liter (70cu.ft.) cylinder in app. 8 min from 0-3000 psi/200 bar
Dimensions	L35" (90) x D34" (90) x H53" (135cm)
Weight	700 lbs (317 kg)

Appendix C – Water Pump Data

8000 PROPELLER PUMPS
PUMP PERFORMANCE



24″
8312

705
RPM

1
STAGE

30″ COLUMN

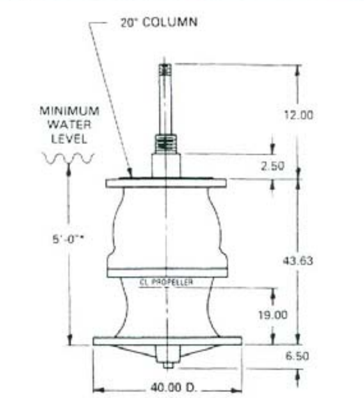
30″ FABRICATED STEEL ELBOW

2-3/16″ LINESHAFT

3″ ENCLOSING TUBE

20,000GPM @ 13.5'TDH (4.11meters)

DATA	VALUE	
PUMP SHAFT DIAMETER	2.4375 IN.	
MAXIMUM SPHERE SIZE	3.75 IN.	
Kt (THRUST FACTOR)	127 LBS./FT.	
Ka (TOTAL ROTOR WEIGHT)	175 LBS.	
Ks (SETTING CONSTANT)	12.8 LBS./FT.	
WK^2	77 LBS.-$FT.^2$	
BOWL ASSEMBLY WEIGHT	1700 LBS.	
EYE AREA: PROPELLER NO. A-360-F	256.3 SQ. IN.	4 VANE
PROPELLER NO. A-361-T	256.3 SQ. IN.	3 VANE
PROPELLER NO. A-362-T	256.3 SQ. IN.	3 VANE
PROPELLER NO. A-363-T	256.3 SQ. IN.	3 VANE
PROPELLER NO.		
PROPELLER NO.		



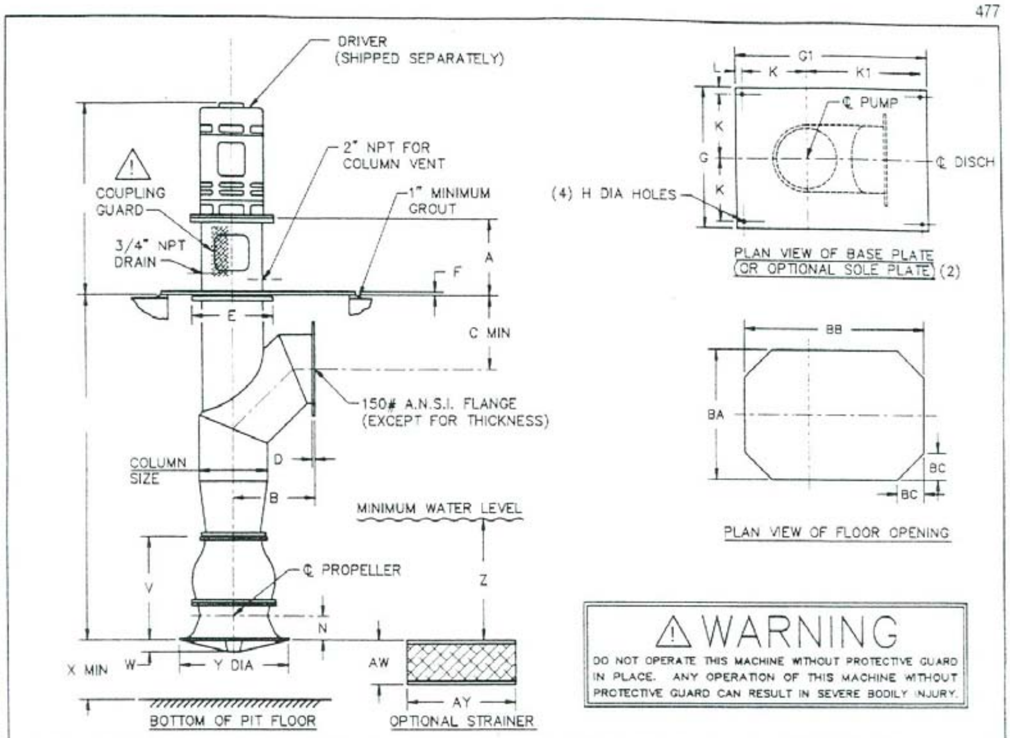
HYDRAULIC PERFORMANCE IS CONTINGENT ON FURNISHING THE PUMP WITH SPECIFIED AMOUNT OF CLEAR, FRESH, NON-AERATED WATER NOT TO EXCEED 85° F.

PUMP PERFORMANCE SHOWN IS BOWL ASSEMBLY WITH 10 FEET OF COLUMN INCLUDING A STANDARD ABOVE GROUND DISCHARGE ELBOW. ADDITIONAL COLUMN LOSSES SHOULD BE ADDED WHEN SETTINGS ARE DEEPER THAN 10 FEET AND/OR FOR OTHER DISCHARGE ARRANGEMENTS.

*This value is the minimum submergence required to prevent vortexing only. This value may need to be increased to provide adequate NPSHA.

FAIRBANKS MORSE PUMPS

477



PEDESTAL AND ELBOW DIMENSIONS

PUMP SIZE	DISCH SIZE	COL SIZE	A MTR BASE DIA 12	16 1/2	20	24 1/2	30 1/2	B	C	D	E	F	G	G1	H	K	K1	L	FLOOR OPENING DIMENSIONS BA	BB	BC
10	10	10	20	--	--	--	--	13	10	3/4	13 3/4	3/4	23	35	7/8	9 1/2	21 1/2	2	18	30	5
10,12	12	12	20	20	--	--	--	15	11	3/4	16 1/4	1	26	40	7/8	11	25	2	21	35	6
12,14	14	14	20	20	24	--	--	17	12	3/4	17 1/2	1	29	43	7/8	12 1/2	26 1/2	2	24	38	7
14,16	16	16	20	20	24	--	--	20	13	3/4	19 1/2	1	32	48	1	14	30	2	27	43	8
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24,30	30	30	--	--	24	24	30	36	20	3/4	34	1 1/2	54	80	1 1/8	25	51	2	45	71	13
30	36	36	--	--	24	24	30	43	24	3/4	40	1 3/4	66	94	1 1/8	31	59	2	57	85	16

PUMP DIMENSIONS

PUMP SIZE	N	V 1 STG	V 2 STG	W	X W/O STR	X WITH STR	Y	STRAINER AW	STRAINER AY	Z
10	7 1/4	17 1/2	30 3/8	3	6	8	15 1/2	5	15 1/2	51
12	9	21 1/2	37	3 1/2	6	12	18	9	18	54
14	11	26	44 1/2	4	7	11	21	8	20 3/4	54
16	12	30	51 1/2	4 1/4	8	10	24 1/2	7	24	57
20	16	38 1/2	66	6	12	12	35	9	35	60
24	19	43 5/8	74 3/8	6 1/2	14	14	40	8	40	60
30	22	51 3/4	89	7 1/2	14	14	42	11	42	64

1. THIS DRAWING NOT FOR CONSTRUCTION OR INSTALLATION UNLESS CERTIFIED. DIMENSIONS SHOWN ARE TYPICAL AND MAY VARY DUE TO VARIOUS TOLERANCES.
2. BASE PLATE (OR OPTIONAL SOLE PLATE) MUST BE SUPPORTED ON ALL FOUR (4) SIDES.

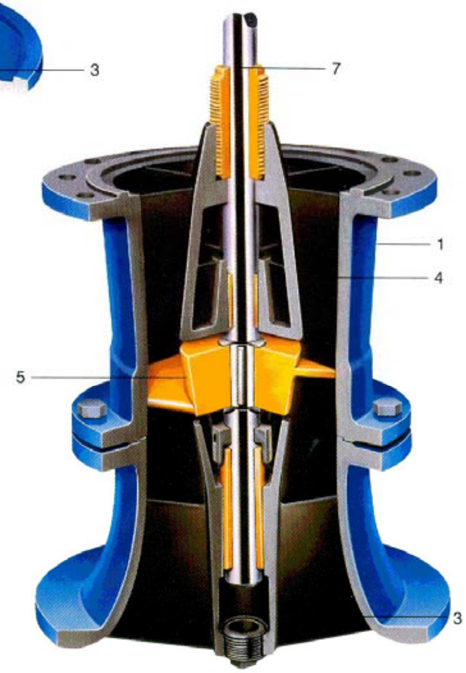
CUSTOMER: VA TECH SENIOR DESIGN TEAM			P.O.			RELEASE NUMBER: EC2-15054	REV NO: 1
JOB NAME: BARGE PUMP		SERVICE				Fairbanks Morse Pump Corporation	
PUMP SIZE & MODEL: 24" 8312	STAGES: 1	GPM: 20,000	TDH: 13.5	RPM: 705	ROT	SETTING PLAN FIGURE 8312 FLANGED DISCHARGE UNDERGROUND HEAD	
MOTOR: VERT. HOLLOSHAFT	HP: 150	FRAME: 5008P	PHASE: 3	HERTZ: 60	VOLTS: 460	ENCL: WP-1	
CERTIFIED FOR		CERTIFIED BY			DATE: 1/10/08	DWG. NO.: 24LYA3523G	

5/9/90

AXIAL AND MIXED FLOW BOWL ASSEMBLIES

5. Axial flow propellers feature well rounded leading edges to prevent accumulation of stringy materials and provide increased solids-passing capabilities. The Model 8211 propellers are secured to the shaft with longitudinal keys and snap rings.
6. The mixed flow propeller design also features well rounded edges and hydrofoil design to pass large diameter solids. These propellers are attached to the shaft with a lock collet and lock nut. (Larger size 8312's also incorporate keys.) All propellers are dynamically balanced to eliminate vibration.
7. Large bowl shafts are of sufficient diameter to transmit the required drive torque.
8. Bowl liners are available to provide a renewable surface and maintain the clearance between the propeller and bowl. Replacement of bowl liners restores worn units to original conditions extending efficient operation for many years.

1. Heavy-duty high quality cast iron bowl castings with smooth passageways enhance efficient operation.
2. Intermediate and discharge bowl bearings are product-lubricated and designed to carry maximum loads over long service life. The suction bowl bearing is grease-packed and fitted with a sand collar for protection from sand and grit.
3. The suction bell features three or four integrally-cast guide vanes to reduce vortexing and entrance losses. The reduced number of vanes allows for passage of solids.
4. Discharge diffuser vanes provide smooth flow entering the discharge column.



Appendix D – Winch Data

Performance Specifications

Ratings and Capacity		
1.1	Safe Working Load	117,694 N (12,000 Kg, 26,460 lbs.) at full drum
1.2	Maximum Line Pull	147,118 N (15,000 Kg, 33,075 lbs.) at full drum (equal to 1.25 times Safe Working Load)
1.3	Line Speed	0.50 m/s (30 mpm, 100 fpm) at full drum, 60 Hz
1.4	Drum Capacity	2,760 meters (9,062 ft.) of 46 mm (1.81 in.) diameter umbilical
Winch Drum Dimensions		
2.1	Drum Core Diameter	1,880mm (74 in.)
2.2	Drum Core Width	2,324 mm (91½ in.)
2.3	Drum Flange Diameter	2,743 mm (110 in.)
Overall Dimensions		
3.1	Length	5,048 mm (198¾ in.)
3.2	Width (across drum face)	3,150 mm (124 in.)
3.3	Height	4,039 mm (159in.)
3.4	Weight (without cable, including power unit)	14,875 Kg (32,790 lbs.)

Appendix E – Diesel Generator Data

XC354

354 kW Cummins Powered
Fully Packaged Diesel Generator

GENERATOR ENGINE

Cummins heavy-duty diesel engines use advanced combustions technology for reliable and stable power, low emmissions, and fast response to sudden load changes.

Electronic governing is available for applications requiring constant (isochronous) frequency regulation such as Uninterruptible Power Supply (UPS) systems, non-linear loads, or sensitive electronic loads. Electronic governing is standard on 100 kW and up. Optional coolant heaters are recommended for all emergency standby installations or for any application requiring fast load acceptance after startup.

Engine Make	Cummins
Engine Model	NTA-855-G3
Cylinders Capacity	3.7 gal (14 L)
Cylinders and Build	6 In Line
Engine Speed	1800 RPM
Bore and Stroke	5.51 in x 5.98 in (140mm x 152mm)
Fuel Consumption	17.44 gal/hr (66 l/hr) @ 3/4 Load
Fuel Tank Capacity	110.95 gal (420 L)

CUMMINS heavy duty diesel engine
Four stroke, water cooled, trubo-charged
Electronic Governor Control System
Direct Injection Fuel System
Replaceable wet type cylinder liners
4 valves per cylinder
24 V D.C. starter and charge alternator
Replaceable fuel filter, oil filter and dry element air filter
Cooling radiator and fan
Starter battery (with lead acid) including rack and cables
Flexible fuel connection hoses and manual sump oil drain valve
Industrial capacity exhaust silencer and steel bellow
Jacket water heater (on automatic models)
Operation manuals and circuit diagram documents

References

[i] NSWCCD-CISD-2007/005, MOSES – Inflatable Causeway; Philip Rosen, Kent Dickens; 28 July 2007

[ii] Jack-up Units, a Technical Primer for the Offshore Industry Professional, Bennett & Associates L.L.C.